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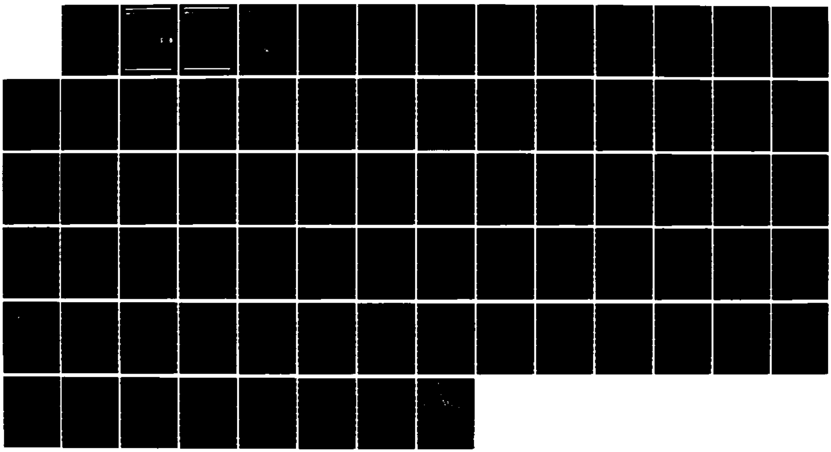

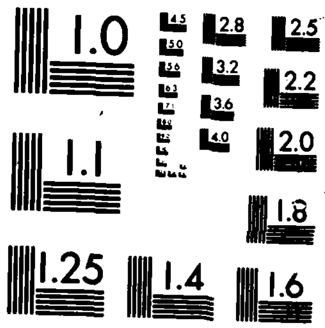

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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GOVERNMENT SYSTEMS DIVISION

8619 WESTWOOD CENTER DRIVE
VIENNA, VA 22180

FINAL REPORT: COMMERCIAL SATCOM SUBARCHITECTURE ASSESSMENTS AND INITIAL CONCEPTS

Final Report 166
Task MSO85-804

November 1985

Prepared by M/A-COM LINKABIT, Inc.
Under Contract DCA100-84-C-0009

Submitted to
Defense Communications Agency
Center for Command and Control,
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CENTER FOR COMMAND AND CONTROL, AND COMMUNICATIONS SYSTEMS (C^4S)

" EXCELLENCE IN C^3 SYSTEMS FOR NATIONAL DEFENSE"

FINAL REPORT: COMMERCIAL SATCOM SUBARCHITECTURE ASSESSMENTS AND INITIAL CONCEPTS

November 1985

DEFENSE
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AGENCY

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SECTION 1

INTRODUCTION

1.1 OBJECTIVE

The DoD currently utilizes a large amount of commercial satellite resources for national and international traffic. These resources are being used by the DoD in a variety of applications ranging from the provision of common user services (such as logistics and administrative communications) to augmenting dedicated military satellite communications (MILSATCOM) operations (for applications such as Attack Warning/Attack Assessment (AW/AA) and sensor connectivity). The increasing DoD reliance on commercial assets, combined with the increased SATCOM resources, are the basis for the development of a commercial SATCOM subarchitecture which would accommodate current and future Government (DoD and non-DoD) traffic scenarios and growth.

The objective of this subarchitecture is to present a cohesive plan for DoD use of commercial communication satellites. The subarchitecture includes summary descriptions of the present and planned, commercial communication satellites; how the DoD uses these resources; and general assessments of how adequately commerical SATCOM systems satisfy DoD communications needs. In addition, the subarchitecture presents alternative concepts for future use of commercial SATCOM as a complement to MILSATs in providing additional service and increasing robust connectivity.

1.2 BACKGROUND

The existing DoD telecommunications capabilities incorporate a mix of media (terrestrial and satellite) and a variety of resources (DoD and non-DoD systems and networks). The reliance of the DoD and other Government agencies on commercial assets is constantly increasing. While current use of commercial assets is based primarily on traditional systems, technologies, and practices, new SATCOM systems and terrestrial networks, incorporating new technologies, are being (or soon will be) introduced. While these developments and the ensuing diversity of commercial systems and networks increase the limitations on interoperability and connectivity, they provide new potentials for improving overall DoD telecommunication capabilities both in peacetime and in various threat environments.

In spite of the increased competition between terrestrial and satellite technologies (i.e., satellite versus fiber optic cables), each media will continue to retain certain inherent advantages. Therefore, SATCOM will continue to play an important role in the provision of DoD and other Government communications, although the extent of this role may differ in international versus domestic communications.

In developing a commercial SATCOM subarchitecture, it is important to clearly identify and distinguish between the roles of military and commercial SATCOM. MILSATCOM will continue to be an indispensable resource in the overall DoD telecommunications assets and capabilitites. The capabilities and design objectives of commercial and military SATCOM differ and often diverge. Typical features of military and commercial SATCOM are compared in Table 1-1.

Table 1-1. Comparison of Military and Commercial SATCOMs

CHARACTERISTIC	MILSATCOM	COMMERCIAL SATCOM
COVERAGE	WORLDWIDE INCLUDING POLAR REGION	DOMSATs: NATIONAL BOUNDARY INTELSAT: NEARLY WORLDWIDE REGIONAL: MEMBER COUNTRIES (NO POLAR COVERAGE)
ORBIT	GEOSTATIONARY AND OTHERS	GEOSTATIONARY
ORBIT UTILIZATION	LOW	HIGH
SPECTRUM UTILIZATION	LOW	FAIRLY HIGH
CAPACITY	MIX OF HIGH, MEDIUM, AND LOW DATA RATES	MEDIUM TO HIGH DATA RATES, HIGH CAPACITY
GRADE OF SERVICE	ACCEPTABLE*	HIGH TOLL QUALITY
RELIABILITY	DEPENDS ON AVAILABILITY OF OF ALTERNATIVES	HIGH IN PEACETIME (ON ORBIT SPARES)
SECURITY (COMMUNICATION, CONTROL)	HIGH	LOW
ANTIJAM	AVAILABLE	NOT AVAILABLE
PHYSICAL HIGH SURVIVABILITY IN STRESSED ENVIRONMENTS	HIGH	LOW

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* DEPENDS ON END INSTRUMENT

Because of the differing and sometimes diverging design criteria, and the generally more advanced MILSATCOM technologies, commercial SATCOM systems are, in general, less costly in terms of dollars per unit of transmitted information than MILSATCOM systems.

Commercial SATCOM should be viewed as a resource which:

- Provides cost effective capacity for less critical DoD users/traffic
- Provides back-up for critical traffic
- Increases DoD communication system robustness
- Allows flexible traffic routing and facilitates network reconfiguration
- Increases MILSATCOM availability for critical or dedicated users through improved allocation of users to military and commercial systems.

Therefore, commercial SATCOM systems could be used as a cost effective complementary system for users not requiring the full capabilities of MILSATCOM systems.

1.3 SCOPE

This document is divided into two parts: Part I addresses domestic SATCOM systems and concepts; Part II provides a similar treatment of international commercial SATCOM assets. Domestic SATCOM systems refer to commercial, U.S.-owned satellite systems that are used primarily for communications within CONUS and in selected cases between CONUS and non-CONUS (e.g., Alaska, Hawaii). International SATCOM include non-U.S.-owned satellite systems, whether used for communications within the U.S. (e.g., ANIK) or between U.S. and other countries, and U.S.-owned satellite systems that may be used for carrying international traffic.

The treatment in each part is subdivided into three time frames: current (1985), mid-term (1986-1991) and far-term (1992-2000).

For the current time frame (1985), existing SATCOM resources are summarized, and a description of how the DoD uses these resources is given.

For the mid-term (1986-1991), planned commercial SATCOM systems are summarized. A description of some major DoD systems/networks, the implementation of which will continue through the mid-term, is given.

For the far-term (1992-2000), potential SATCOM systems and new technologies are first discussed and the role of commercial SATCOM identified. Concepts that will improve the use of commercial SATCOM by the DoD are proposed.

These concepts focus on the use of commercial satellites with terrestrial links (i.e., tails) considered part of the SATCOM system. The potential benefits of the proposed concepts

are based on new systems, technologies, capabilities, and regulatory developments. Furthermore, it is the goal of these concepts to achieve diversity in communication media and systems, robustness, interoperability, flexible routing, interconnectivity, and growth.

The far-term portions of this subarchitecture should be considered preliminary. Further refinements of the concepts presented are necessary.

The concepts and proposals contained in this subarchitecture represent the views of MSO. They do not necessarily reflect a concensus of opinion by the total MILSATCOM community.

PART I

DOMESTIC SATCOM

SYSTEMS AND CONCEPTS

SECTION 2

CURRENT DOMESTIC SYSTEMS AND PRACTICES

Current (1985) DoD domestic telecommunications capabilities consist of a large number of networks that use military, commercial, dedicated, and non-dedicated (i.e., shared) terrestrial and satellite systems/media. In this section, existing domestic commercial SATCOM systems are reviewed, current DoD networks and practices are summarized, and an assessment as to how well these networks and systems meet DoD requirements is given.

2.1 SYSTEMS

2.1.1 Space Segment

Several domestic commercial SATCOM systems are being used to provide a wide spectrum of communications services. These systems are owned and/or operated by several companies. Typical systems (operators) are SATCOM (RCA-Americom), SPACENET (GTE Spacenet), Galaxy (Hughes Communications, Inc.), TELSTAR (AT&T Communications), COMSTAR (COMSAT General), WESTAR (W.U. Telegraph), SBS (Satellite Business Systems) and GSTAR (GTE Satellite). Most of the existing commercial satellites operate in the C-band (i.e., 6/4 GHz), although some operate in the Ku-band (i.e., 14/11 GHz), and others are hybrids operating at both frequency bands (SPACENET). However, the number of Ku-band satellites will increase in the future.

The characteristics of the various C-band systems are similar. Typical C-band spacecraft parameters are summarized in Table 2-1 below.

Table 2-1. Typical C-Band Satellite Parameters

NUMBER OF TRANSPONDERS	24
TRANSPONDER BANDWIDTH	36 MHz
TRANSPONDER EIRP	34 dBW
COMMUNICATIONS FREQUENCIES	
TRANSMIT	3.7-4.2 GHz
RECEIVE	5.925-6.425 GHz
POLARIZATION	LINEAR
G/T	−4 to −7 dB/°K (CONUS)
SATURATION FLUX DENSITY (NOMINAL)	−80 dBW/m²

Table 2-2 summarizes some of the general characteristics for typical Ku-band satellites.

Table 2-2. Typical Ku-Band System Characteristics

SYSTEM AND FREQ. BAND*	NO. OF TRANSPONDERS	TRANSPONDER BANDWIDTH	EIRP	POLARIZATION
SBS, Ku	10	43 MHz	40-44 dBW	LINEAR
GSTAR, Ku	16	54 MHz	40-42 dBW	LINEAR
SPACENET (HYBRID)				
C-BAND	18	36 MHz	33-35 dBW	LINEAR
Ku-BAND	6	72 MHz	~40 dBW	LINEAR

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All of the systems provide CONUS coverage, and some are capable of providing coverages for Alaska, Hawaii, and/or Puerto Rico. The nominal G/T level for a Ku-band satellite is about 2 dB/°K depending on the system.

2.1.2 Earth Segment

The ground segment of the C-band domestic SATCOM generally consists of two types of terminals: trunking terminals that are capable of high throughput capacity (i.e., single carrier

per transponder) and dedicated terminals designed to support a smaller capacity. Typical characteristics of these terminals are summarized in Table 2-3.

Table 2-3. Typical C-Band Terminal Characteristics

CHARACTERISTIC	TRUNKING	DEDICATED
ANTENNA SIZE (METERS)	10-30	4.5-15.5
EIRP (dBW)	80-92	45-80
G/T (dB/°K)	31-42	23-33
POINTING ABILITY	FULL	PARTIAL TO FULL
POLARIZATION AGILITY	MOST	SOME
FREQUENCY AGILITY	MOST	SOME
MULTIPLE ACCESS	TDMA, FDMA	TDMA, FDMA
MODULATION	QPSK, DPSK, FM	QPSK

In the above table, TDMA and FDMA refer to Time and Frequency Division Multiple Access, respectively. QPSK refers to Quadrature Phase Shift Keying, DPSK refers to Differential Phase Shift Keying, and FM refers to Frequency Modulation.

Ku-band dedicated earth terminals, however, are more polarization agile and frequency agile than their C-band counterparts because of their advanced technological systems. The characteristics of typical Ku-band U.S. domestic earth terminals are summarized in Table 2-4 below.

Table 2-4. Typical Ku-Band Terminal Characteristics

CHARACTERISTIC	TRUNKING	DEDICATED
ANTENNA SIZE (METERS)	7-12	1.2-5
EIRP (dBW)	80-90	50-80
G/T (dB/°K)	32-34	16-27
POINTING ABILITY	FULL	FULL
POLARIZATION AGILITY	MOST	MOST
FREQUENCY AGILITY	MOST	MOST
MULTIPLE ACCESS	TDMA	FDMA/FDM, TDMA
MODULATION	QPSK	BPSK, QPSK

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2.1.3 Control Segment

Current U.S. domestic SATCOM are built by the Hughes and RCA Corporations. Although differences in telemetry, tracking and control (TT&C) systems exist, there are some similarities.

The command signals transmitted by the TT&C ground station are received and demodulated by the satellite command receiver and then decoded and fed to the control equipment. The command process includes error correction and verification but no encryption. As a protection AT&T employs a "command intrusion detector" that affords some shielding against deliberate spoofing, while American Satellite Corporation plans to use the Data Encryption Standard (DES) for its command link in the mid-term. TT&C earth stations are generally 10m or more in size and are typically designed to provide large link margins.

For telemetry, various housekeeping data, showing the overall status of different portions of spacecraft, are multiplexed and coded to modulate a beacon frequency for reception at a TT&C earth station.

All common carriers have a central monitor and control (M&C) terminal that usually is incorporated at the TT&C sites. The M&C consists of monitoring equipment that analyzes the transmission parameters of all participating terminals. Deviations from planned usage are identified, and appropriate actions are taken.

There are orderwires between the M&C site and other terminals. These orderwires can be on separate channels or can be incorporated into the main network communications structure, as is the case in all TDMA networks. The existence of the M&C is essential to satisfactory network operation.

It is anticipated that none of these M&C terminals will be operational in post-attack; therefore, if centralized network control is to be used, appropriate backup would be needed.

2.2 CURRENT GOVERNMENT USE OF COMMERCIAL SATCOM

The C-band space segment of domestic SATCOM is used extensively to provide SATCOM services for DoD and other Government agencies. There are three ways in which commercial SATCOM services are provided to DoD and other Government users [1]. These are:

- dedicated Government service using dedicated Government service earth stations,
- dedicated Government service using dedicated Government equipment in general service earth stations, and
- Government service using general service networks (private-line service).

2.2.1 Dedicated Government Service Using Dedicated Government Service Earth Stations

There are 85 Government service earth stations owned by the four common carriers as shown in Table 2-5. These earth stations are leased by the Government and are used to provide dedicated Government services.

Table 2-5. Distribution of Government Service Earth Stations Among the Four Common Carriers

RCA AMERICOM	21
WESTERN UNION TELEGRAPH	16
AT&T	3
AMERICAN SATELLITE COMPANY	45
TOTAL	85

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These Government-dedicated networks use approximately 14 percent of the present commercial service. Dedicated Government circuits are provided through 105 dedicated common user networks consisting of 2 to 10 earth stations each. An earth station may be the nodal point for one or more networks. While there are a few circuits operating at 4 Mbps and some at up to 60 Mbps, the bulk of the dedicated Government services are digital at rates up to 1.5 Mbps. The carrier types and data summaries are given in Table 2-6.

In addition to the leasing of complete earth stations, satellite transponder capacity is also leased to establish these small dedicated networks. This form of service is provided to specific user groups, such as the Ballistic Missile Early Warning System (BMEWS), which includes connectivity via both WESTAR and ANIK B satellites.

2.2.2 Dedicated Government Service Using Dedicated Government Equipment in General Service Commercial Earth Stations

Dedicated Government services are also provided through dedicated Government networks using Government-owned, dedicated equipment installed in general service earth stations. These dedicated Government networks share the HPAs, LNAs, antennas, and diplexers with private-line service, but provide their own modems and dedicated terrestrial transmission equipment.

These networks are generally provided by GSA, and, in many cases, one end of the circuits involved fall into the previous category (see Section 2.2.1). That is, one end of the circuits uses a dedicated Government service earth station, while the other end uses dedicated Government equipment in a general service earth station.

Table 2-6. User and Carrier Type Summary

USER AND NUMBER OF NETWORKS				CARRIER TYPE	
NASA	GSA	DoD	OTHER		
1				SCPC/FM	9.6 Kbps
		1		SCPC/BPSK	16 Kbps
3		2		SCPC/QPSK	50 Kbps
4				SCPC/BPSK	56 Kbps
7		10		SCPC/QPSK	56 Kbps
		1		SCPC/QPSK	64 Kbps
		2		SPCP/QPSK	128 Kbps
		1		TDM/QPSK	193 Kbps
1		1		SCPC/BPSK	224 Kbps
2				SCPC/QPSK	224 Kbps
1				SCPC/QPSK	230.4 Kbps
		1		SCPC/QPSK	256 Kbps
		1		SCPC/QPSK	384 Kbps
1				ANALOG	398 KHz
		1		SCPC/QPSK	512 Kbps
1				TDM/QPSK	540.4 Kbps
		1		ANALOG	550 KHz
		1		SCPC	550.5 Kbps
3				SCPC/QPSK	1330.8 Kbps
		1		SCPC/QPSK	1536 Kbps
6	6	7		SCPC/QPSK	1544 Kbps
		1		TDMA/QPSK	3088 Kbps
2				SCPC/QPSK	4000 Kbps
1				SCPC/QPSK	15050 Kbps
	3			TDMA/QPSK	60000 Kbps
			1	TDM/TDMA	60000 Kbps
5		1		SCPC/FM	
5				SCPC/FM/AVD	
2				SCPC/FM/VOICE	
1				FDM/FM/12	
1			2	TELEVISION	
			1	SCPC/FM/AUDIO	5 KHz
			1	SCPC/FM/AUDIO	
1				SCPC/QPSK	56, 1544 Kbps
1				SCPC/QPSK	56, 22, 1344 bps
		1		SCPC/QPSK	56, 100, 1344 bps
		2		SCPC/QPSK	56, 768, 1544 bps
		1		SCPC/QPSK	50, 56 Kbps
		1		SCPC/QPSK	50, 1544 Kbps
		1		SCPC/QPSK	192, 1544 Kbps
		1		SCPC/QPSK	230.4, 3072 Kbps
		1		SCPC/QPSK	384, 512, 3072 Kbps
		1		SCPC/QPSK	386, 579, 1158 Kbps
49	9	42	5	= 105 NETWORKS	

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IN THIS TABLE, THE ACRONYMS ARE AS FOLLOWS: SCPC REFERS TO SINGLE CHANNEL PER CARRIER (A FORM OF FREQUENCY DIVISION MULTIPLE ACCESS, FDMA), TDM AND TDMA REFER TO TIME DIVISION MULTIPLEXING AND TIME DIVISION MULTIPLE ACCESS, RESPECTIVELY, FM REFERS TO FREQUENCY MODULATION, AND QPSK INDICATES QUADRATE (FOUR-PHASE) PHASE SHIFT KEYING.

2.2.3 Government Service Using General Service Networks (Private-Line Service)

The Government currently relies heavily on commercial assets to meet its telecommunications needs. Most of the Government's communications requirements are provided by common user networks through commercial carriers. These networks provide private-line service through general service earth stations in combination with conventional landline access and transmission facilities. Point-to-point channels for voice, data, facsimile, and various wideband applications are provided by common carriers such as RCA Americom, ASC, AT&T, GTE, and WU Telegraph.

In 1985, the DoD will lease $1.9 billion in telecommunications capabilities from commercial carriers, while the overall Government (DoD and non-DoD) leases will total $3.2 billion. Of the 122,000 Government CONUS circuits, 92 percent are provided by commercial firms, and 96 percent of the 13,400 critical circuits (restoral priorities 1-4) are provided by commercial firms.

In general, individual point-to-point DoD circuit leases are imbedded in the general service networks operated by the common carriers. These circuits use both terrestrial and satellite facilities and serve DoD functions such as defense, command and control, and intelligence and use the complete spectrum of commercial satellite carriers.

2.3 ASSESSMENT OF CURRENT SYSTEMS

Although the existing overall domestic commercial system is robust and incorporates connectivity and media diversity, current practices for taking advantage of these assets do not fully utilize these potentials.

The increased competition within the communications industry, the introduction of new and diverse systems, and improved technologies offer new challenges and allow more effective use of commercial assets. In particular, these factors can be used to improve the robustness of the total MILSATCOM system through:

- Diversification of communications media and connectivity within the MILSATCOM system.
- Taking advantage of the large number of commercial satellites and improving interoperability between the various SATCOMs.
- Allowing flexible growth in accommodating new users, services, and technologies.

In what follows, some of the areas requiring improvements are identified for each of the current methods of utilizing commercial SATCOM. These methods as described in the previous section are:

- Dedicated Government service using dedicated Government earth stations.
- Dedicated Government service using Government designated equipment in general service commercial earth stations.
- Government service using general service networks (private-line service).

The first two methods do provide some limited flexibility in using the available bandwidth to support voice and various data rates. This is due to the fact that the Government has more control over the use of available assets than when point-to-point circuits are leased through the general service networks. However, the diversity of and the lack of interoperability among the satellites, earth terminals, and networks preclude any connectivity flexibility except within individual networks, and between certain networks that share a common terminal or a node.

The third method of supplying service provides very little flexibility in using these assets for other than the specific use originally intended. The end points, the terminal equipment, and the communications paths are essentially fixed and are not readily reconfigurable for use in reconstituting other services or in establishing alternate connectivity and paths.

SECTION 3

MID-TERM DOMESTIC SYSTEMS AND NETWORKS

In this section, mid-term (1986-1991) domestic SATCOM systems are discussed and the role of these systems in the development of a commercial subarchitecture is outlined. Finally, a general assessment of the various domestic networks that are being implemented or planned is given.

3.1 DOMESTIC SATCOM SYSTEMS

The various domestic SATCOM systems discussed in the previous section for the near-term are expected to continue through the mid-term. During the 1986 to 1991 time frame many additional spacecraft will be deployed to expand the systems and capabilities presented earlier. Furthermore, the introduction of several new systems is planned. American Satellite Company (ASC), U.S. Satellite Services Inc., Ford Aerospace Corp., Advanced Business Communications, Rainbow Satellite Inc., and Martin Marietta are some of the commercial companies that have been reported as planning their own systems.

The majority of new satellites to be introduced in the mid-term are Ku-band satellites[2], although some C-band spacecraft are planned to replace or complement those already in orbit. The various Ku-band satellites will basically employ existing technologies and will continue to have varying characteristics. These satellites will have 10, 16, 20, 24, and 28 transponders per spacecraft. Some will incorporate higher EIRP levels, ranging from 38-60 dBW.

The large expansion of domestic Ku-band resources in the mid-term is an important consideration. Ku-band systems allow use of smaller earth stations and are not vulnerable to the terrestrial interference experienced at C-band. These systems provide an attractive alternative to C-band in the development of a commercial SATCOM subarchitecture. All of these attributes would complement MILSATCOM systems and enhance the desired robustness and capabilities described in Section 2.3.

3.2 THE ROLE OF COMMERCIAL SATCOM: A COMPARISON OF SATELLITE AND FIBER OPTICS TECHNOLOGIES

Although an overall architecture is expected to incorporate a variety of communications media, including satellite links (commercial and military) and terrestrial links (cables and microwave), satellites will continue to be the preferred alternative in certain applications, while terrestrial fiber optic links will dominate in others.

In the near and mid-terms, the significant advances in fiber optics technology are expected to continue. New technologies (i.e., single mode and dispersion shifted fibers) are drastically reducing the dispersion that limits performance, thus allowing higher bit rates and longer distances between repeaters[3,4]. Lasernet and AT&T are examples of domestic fiber optic networks that are being installed or expanded. (AT&T's multimode, 90 Mbps, fiber links installed in 1983 are being expanded using single-mode fibers, which can transmit at 565 Mbps). Transmission rates of up to 2.4 Gbps are expected by 1991-1992.

In addition to increased capacity and reduced cost, attractive features of fiber optics links include reduced susceptibility to noise and electromagnetic interferences from outside sources, improved security due to the absence of radiation

leaks, difficulties in intercepting or tapping optical signals, and reduced transmission delay compared to satellite links. Fiber optics links are expected to dominate in point-to-point routes with heavy traffic.

On the other hand, several inherent features combine to make satellites the primary, and sometimes the only, practical communications medium in several applications. These features and capabilities include: the flexibility to redeploy and/or reconfigure satellites to cover different geographical regions; relative insensitivity to distances; and the ability to provide full connectivity among all earth stations/nodes in the network. Applications that are expected to continue to rely on satellites include point-to-point thin route services, point-to-multipoint (broadcast) services, and point-to-point or broadcast services involving mobile or transportable terminals.

Determining the appropriateness of a given communication medium will depend on several other considerations, including: network topology; the location of nodes/users; their connectivity requirements; cost effectiveness; communications performance; link availability requirements; vulnerability to jamming and interferences, survivability, and security of the communication medium, etc.

3.3 DOMESTIC NETWORKS: DoD USE OF COMMERCIAL ASSETS

Several DoD communications systems and networks (terrestrial and satellite) are being planned or implemented. Their implementation will continue through the mid-term. In this section, these networks and systems are discussed, and the projected use of commercial SATCOM in these networks is outlined.

The current practice of obtaining individual circuit leases and small dedicated networks will no doubt continue into the mid-term. However, a new program, the DoD/GSA Commercial Telecommunication System (DCTN), recently awarded to AT&T, will employ, in part, commercial satellites to provide both trunking and networking for such services as switched voice, point-to-point data and video teleconferencing. The acquired services represent a consolidation of many of the Government's requirements for telecommunications. The implementation of DCTN will provide nine new transmit and receive earth stations and several receive-only earth stations located on or near major DoD installations.

Commercial satellites are also expected to play a major role in providing trunking to networks such as the Defense Switched Network (DSN) and to the Public Switched Network (PSN) in support of the National Emergency Telecommunications System (NETS). The DSN is a common-user, direct-dial telecommunications network for the United States military forces worldwide. It is intended to replace the services and capabilities of the present AUTOVON network and to form the basis for new and improved services for its users. The architecture for DSN in the CONUS has not been finalized. However, an evaluation of the best mix of Government-owned facilities and leased services is being performed. Regardless of the outcome, DSN is committed to providing diverse transmission media to ensure a robust and flexible network. Therefore, commercial satellites are likely to play a significant role in providing inter-switch connectivity. Since the precise role of commercial satellites in DSN has not been determined, the potential for a viable commercial SATCOM architecture to influence this use is great.

NETS is intended to provide critical Government communications in national emergencies, including in post attack. NETS relies on the inherent widespread connectivity of the Public Switched Network (PSN). Through the use of call control modules (CCM) located at selected Class 4/5 switches, NETS will allow specific, critical users special call-routing features, which attempt to circumvent damaged facilities and portions of the network, thus increasing the probability of call completion. However, call connection time may be very long and the voice quality degraded. While the final configuration of NETS has not yet been specified, the National Communications System (NCS) has already identified a number of PSN nodes for commercial satellite augmentation. This augmentation is intended to improve inter-enclave connectivity in post attack by providing additional interswitch trunking that would be activated when terrestrial trunking is destroyed.

3.4 ASSESSMENT OF MID-TERM SYSTEMS

Since many of the current practices for obtaining Government services will continue into the mid-term, the same lack of flexibility exhibited by these practices (see Section 2.2) will also continue. In addition, more and more systems are being developed in the commercial sector to capitalize on the ever increasing demands for telecommunications services. These systems are incompatible among the different manufacturers and very often among equipments of the same manufacturer. This fact will further complicate the problems of exploiting the numerous and diverse capabilities of the commercial services.

Interoperability, therefore, becomes an important consideration in the development of a commercial SATCOM subarchitecture

that can capitalize on these numerous systems to improve the robustness of the overall DoD capabilities.

The existing domestic systems will experience many changes in the mid-term, such as:

- the number of domestic SATCOM systems will increase to accommodate the growth in domestic traffic requirements,
- some of these systems will incorporate advanced technologies,
- the role of fiber optics will become increasingly important because of the additional capacity fiber optic cables can provide, and
- the divestiture of AT&T will permit new domestic carriers and networks and increased competition.

All of these are major factors that will affect future DoD use of commercial assets. The introduction of such new diverse systems, networks, and technologies offers new challenges and potentially allows more effective use of commercial assets.

3.5 THE INITIAL CSS CONCEPT

Presidential Directive NSC-53 and National Security Decision Directive-97 (NSDD-97) recognize the Government's dependence on common carrier networks and the necessity to achieve a survivable communications system. This requirement led to the establishment of the National Security Telecommunications Advisory Committee (NSTAC), a presidential advisory committee comprised of Government and industry representatives. The Commercial Satellite Survivability (CSS) task force has been charged by NSTAC to address commercial SATCOM enhancement issues.

The Commercial Satellite Survivability (CSS) program is an ongoing effort aimed at reestablishing connectivity between a set of surviving Public Switched Network (PSN) nodes by providing commercial SATCOM transmission in a post attack environment. The initial architecture focuses primarily on the domestic PSN in combination with C-band commercial SATCOM assets. This section highlights some of the important features of this architecture. It should be recognized that the treatment here is not comprehensive since the initial CSS configuration is continuing to evolve, thus the discussion will emphasize those established features that are not expected to change.

3.5.1 Framework and Assumptions

The scope of the initial architecture encompasses the surviving elements Public Switched Network in combination with commercial C-band domestic SATCOM assets in post-attack environment. In particular, the SATCOM assets considered include C-band commercial two-way terminals that are operational with domestic commercial SATCOM having CONUS coverage. The portion of the PSN that is a candidate for

SATCOM connectivity are the No. 4 ESS switches of the AT&T network.

In this context, the initial architecture was developed based on the following assumptions and guidelines:

- Procurement of new earth stations (transportable or fixed) is undesirable; only modifications to existing ones so that a low cost implementation may be possible.
- Post-attack activation assuming a massive nuclear exchange has occurred.
- A specific set of PSN switches and/or earth stations and TT&C facilities have a high probability of surviving a nuclear attack.
- The communications terminals and control facilities that are likely to survive attack on CONUS are fragmented to a degree that severely limits their ability to communicate with each other.
- A surviving C-band spacecraft will exist.
- Only C-band assets are considered in the initial CSS architecture.

3.5.2 Features

The CSS concept features are based on the following analysis. Using a prescribed threat scenario, PSN switches and large C-band earth stations having a high probability of survival were identified. Available connectivity (post attack) and special users requirements between surviving switches were examined. Of the surviving PSN nodes, a subset was identified as requiring connectivity.

The fundamental feature of the CSS concept is to provide the required connectivity among the above switches by using surviving C-band earth terminals that are nearest to those switches. To make this possible, the concept is to augment the

capability of these terminals to provide the required links by adding certain equipment (e.g., modems) and to lease terrestrial links between each pair of identified earth station/PSN node.

The number of PSN nodes/terminals that are recommended or subject to this augmentation is not likely to exceed 20 for the initial architecture.

In a post-attack environment and when the decision is made to activate the CSS capabilities, these earth stations would repoint their antennas to a designated surviving satellite and create a new network. The activation of CSS would provide needed post-attack communication for certain special users.

The disruption of the peacetime connectivity is considered of little consequence since these connectivities are assumed to be no longer a requirement in the post-attack. Furthermore, based on the assumed threat scenario, the current terrestrial tails to these earth stations are not expected to survive since they are originated in major metropolitan areas.

3.5.3 Advantages and Disadvantages

The fundamental benefit of the initial CSS is that it provides a cost effective means for establishing new links that are perceived as vital requirements in a post-attack environment in support of the National Security and Emergency Preparedness (NSEP). The implementation of a small number of switch/terminal augmentations is aimed at achieving two goals. The first is the provision of a minimum essential capability supporting specialized users in the post-attack. The second is the low cost and ease of implementation so that for a reasonable cost, the system can be fielded and be operational in the mid-term. This provides a basis for further expansions in the

far-term and avoids funding problems for a very large program involving the purchase of new terminals.

The disadvantages of CSS fall into two areas. The first area deals with the small number of augmented switches/terminals for the initial architecture. There is a lack of robustness in such a sparse system, since if the attack scenario is changed, augmented switches/terminals may be lost. However, it must be emphasized that many of these earth stations, for frequency clearance reasons, are located well outside the metropolitan areas and are therefore considered less susceptable to threat scenario changes. For the small number (less than 20) of switches/terminals augmented, it is conceivable that they may themselves become high-value targets to the enemy.

The second area of disadvantage concerns the effect of the activation of the CSS network on the overall post attack network. The premise of CSS to be a post-attack system precludes use of CSS if less than a massive attack occurs. The activation of CSS in any scenario other than after a massive attack may result in the elimination of a large number of undamaged links and a loss of significant capacity. This is because once an earth station becomes a member of the PSN augmentation network, it may no longer be fully capable of communicating with other, non-CSS-compatible, earth stations.

In the far-term, an architecture that addresses the areas not covered by the initial CSS and that more fully utilizes the inherent robustness of the PSN is highly desirable.

SECTION 4

FAR-TERM DOMESTIC SYSTEMS, TECHNOLOGIES, AND CONCEPTS

This section discusses far-term (1992-2000) domestic SATCOM systems and technologies and presents concepts for improved use of commercial SATCOM by the DoD.

4.1 DOMESTIC SATCOM SYSTEMS

The various C-band and Ku-band systems presented for the current and mid-terms are expected to continue providing domestic SATCOM services over CONUS. Given the 10-year spacecraft design life that is achievable today, the various satellites to be deployed during the mid-term are expected to continue their services through the mid-to-late far-term (beyond 1995).

In the far-term, new satellites will replace and expand commercial SATCOM resources. Although specific far-term spacecraft designs and technologies are yet to be determined, commercial SATCOM, incorporationg new technologies, are expected to emerge. Such technologies and their potential benefits are discussed in the next subsection.

Far-term commercial SATCOM spacecraft concepts, which are receiving increased attention by private industry, include mobile satellite systems. M-SAT is one example of mobile SATCOM and has been under consideration as a joint Canadian-U.S. effort. M-SATs are en- visioned to provide communications for users during movement: by foot, on ship, or by land vehicle. M-SATs service areas would be the U.S. and Canada. Uplink transmissions would be at 821-825 MHz and 14 GHz bands; downlink transmission could use the frequency bands at 866-870 MHz and at 12 GHz. Advances dramatically increasing

system capacity will be required. The earth segment may use a drooping dipole (a man-steered antenna, 4 dbi gain), quadrafile or planar arrays.

4.2 FAR-TERM TECHNOLOGIES

Far-term new technologies will generally follow, and be dependent upon, the success of mid-term research and development programs, such as NASA's Advanced Communications Technology Satellite (ACTS) program. Due to increased demand and the need for more efficient use of spectral and orbital resources, future commercial SATCOM systems are likely to incorporate new technologies such as:

- On-board processing and switching
- Narrow, focused beams
- Hopping beams
- New frequencies such as Ka-band (30/20 GHz)
- Solid state and Microwave Monolithic Integrated Circuit (MMIC) technologies.

The potential advantages offered by these technologies are many, including:

- More bandwidth available at Ka-band versus Ku- or C-band
- Smaller earth station size ($\leq$ 2m antennas) assuming Ka-band systems incorporate narrow beams and higher EIRP
- Increased capacity due to on-board processing and/or frequency reuse with hopping beams
- Increased flexibility in routing and interconnectivity (due to on-board switching)
- Reduced vulnerability to jamming and interference offered by narrow hopping beams
- Improved reliability and reduced cost when solid state and MMIC technologies are used.

Future deployment of domestic SATCOM systems incorporating new technologies depends on the system requirements and cost, as well as other factors, such as launch dates. One fact is clear: the increased congestion of the lower frequency bands will force development of new systems at Ka-band. NASA's ACTS program will facilitate the movement to the Ka frequency band.

4.3 NETWORKS AND CONCEPTS

Architectures and networks for the provision of DoD and other Government communications will incorporate several communications media and systems including commercial and military, satellite and terrestrial assets. The role of terrestrial links in providing a large portion of the domestic DoD and other Government communications will no doubt continue, particularly in the area of point-to-point trunks using fiber optics connectivity.

Some of the inherent features of SATCOM were outlined in Section 3.2. A concept, which takes advantage of some of these features to improve the robustness of the overall domestic telecommunication capabilities, will be presented and discussed in the following sections. To guide in the development of this concept, however, the following general assumptions are made:

- Existing common-carrier communication networks have a high degree of survivability (i.e., rich and widespread connectivity).
- Future improvements (e.g., fiber optic cables) will, in many cases, increase survivability.
- The DoD or the U.S. Government will not directly influence the design of the existing commercial communication systems by directly funding additions.
- The extent of damage to the network at any given time is unknown; the damage may range from the outage of a few links to massive outages of both nodes and links.

- The probability associated with any given level of destruction is unknown.
- If a system is constructed to improve the robustness, it should be useful at any level of devastation.

4.3.1 Basic Concept

A concept is proposed for the far term to add an overlay network to the existing commercial network and to provide improved robustness and additional connectivity. The connectivity of the existing or base network does not need to be altered at any time to accommodate the added, or overlay, network.

More specifically, the overlay network is established by adding commercial satellite terminals at selected nodes within the existing network. The terminals would be located at the class 4 switch level of the network and other user concentration sites. Initially, all terminals would operate through one satellite but with planned extension through additional satellites. The network would be designed to allow any terminal to communicate with any other terminal, in other words, full mesh connectivity.

The capacity of the added network is to be assigned dynamically amongst the nodes of the added network to best serve the needs of the base network.

4.3.2 Concept Features and Variations

As indicated above, an important feature of the proposed concept is its use of the inherent satellite feature of full connectivity to establish a single hop mesh network. This type of mesh network, though easily implemented through commercial

SATCOM, would be a costly and complex process to implement terrestrially. (A mesh network is illustrated in Figure 4-1.) SATCOM can more cost effectively provide connectivity between any two or more surviving network nodes (provided a commercial SATCOM that can be used by the network has survived). Furthermore, the overlay network could provide alternate communications paths between terminals or users. This alternate routing would be available in case of a failure of, or damage to, an intermediate switch linking these users terrestrially. More generally, SATCOM alternate routing is advantageous in overcoming or bypassing single point failures.

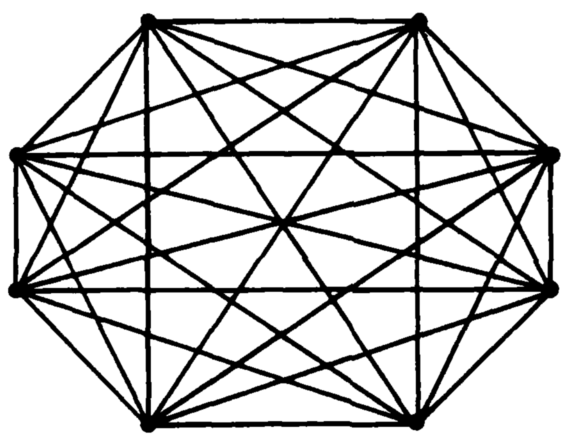

Figure 4-1. An Example of a Fully Connected, Mesh Network With 8 Nodes

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The user and traffic requirements and distributions are essential considerations in determining the overlay network capacity and the number of nodes or terminals and their locations.

The capacity requirements are expected to be met using several transponders. The earth terminal designs would allow interoperability between the various earth stations and transponders. Although these transponders may initially be provided by a single satellite, earth terminal designs that would allow operations with different satellites can significantly enhance the earth segment interoperability (using different satellites) and, hence, the robustness of the network. The provision of earth terminal flexibility to interoperate using different satellites is expected to require consideration of a particular class of satellites. This expanded earth-space segment interoperability, using different satellites, is a key feature. Although individual commercial satellites lack the survivability features of MILSAT, the availability of a large number of commercial satellites can be exploited to provide a more robust network.

Among the variations within this concept are the use of Ku-band satellites with smaller terminals and TDMA/DAMA to provide a more dynamic and flexible allocation of space segment capacity resources.

The TDMA variation lends itself well to accommodate new users, services, and technologies. The basic network features would be retained as new users enter the system. In addition, if the TDMA earth stations within the network are not committed to a single spacecraft (or transponder), their designs could allow for changing satellites even if the new satellite incorporates new technologies, such as beam hopping and on-board processing.

Another feature of the basic concept is the flexible network expansion in allowing new earth stations to join the network while retaining full mesh connectivity. Furthermore, another network using a different satellite could be established with an earth station in one network capable of be-

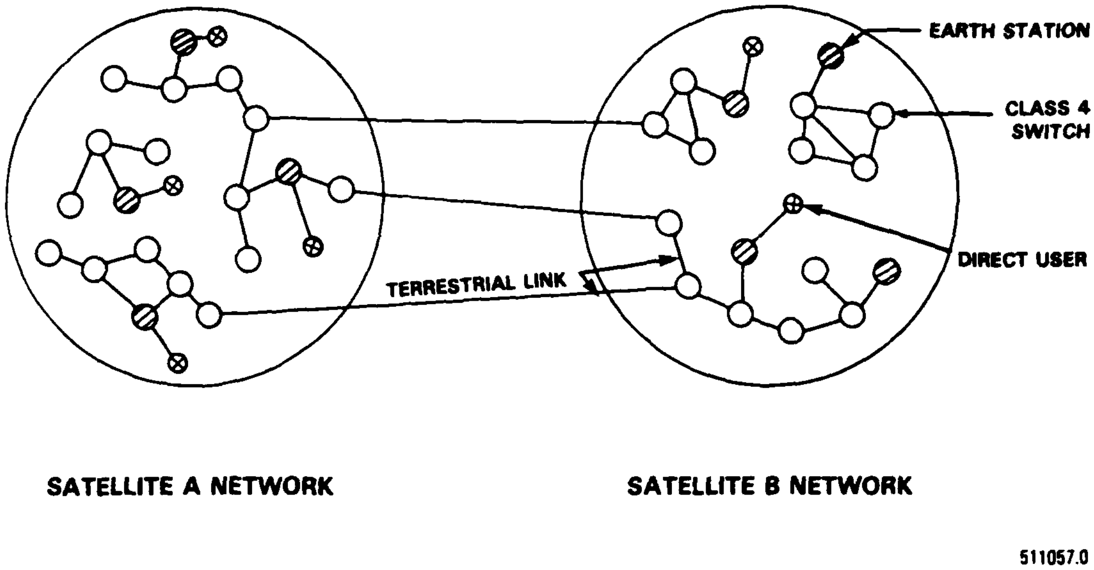

Figure 4-2. Overlay Networks with Multiple Satellites

coming a member of another. Figure 4-2 illustrates an example of two networks. Note that an earth station could handle direct-access users, as well as class 4 switch traffic.

The robustness of the satellite and network control facilities is a key element in the development of any commercial SATCOM subarchitecture. To improve this robustness, appropriate measures (e.g., redundancy and/or distributed control) may be incorporated into the proposed concept. A tradeoff exists, however, between the extent of this improvement and the associated cost and complexity.

4.3.3 Concept Advantages and Disadvantages

The main benefits of the recommended far-term concept are summarized in Table 4-1. Important benefits of the proposed concept are that it is fully usable during peacetime, the network is fully expandable to accommodate changing

Table 4-1. Domestic SATCOM Concept Benefits

I. MAJOR BENEFITS:
1. FULL USE IN PEACE-TIME. ECONOMIC BENEFIT FROM INVESTMENT.
2. FLEXIBLE ROUTING, FULL MESH CONNECTIVITY CAPABILITY BETWEEN SURVIVING CLASS 4 SWITCHES AND DIRECT ACCESS USERS.
3. CAPABLE OF OPERATING WITH DIFFERENT Ku-BAND SATELLITES AND NON-PROCESSING TRANSPONDERS: INTEROPERABILITY.
4. FULLY EXPANDABLE AND IMPLEMENTABLE IN SMALL STAGES.
5. GRACEFUL DEGRADATION AS TERMINALS BECOME INOPERATIVE, PARTICULARLY IN AN EXTENDED ATTACK SCENARIO.*

II. OTHER BENEFITS:
1. SMALLER EARTH STATIONS WITH COMPATIBLE DESIGNS (PARTICULARY BASEBAND).
2. CAN ACCOMMODATE MOBILE/TRANSPORTABLE COMMUNICATION EQUIPMENT.
3. IN PLACE AND FULLY OPERATIONAL WHEN NEEDED.
4. DIRECT ACCESS TO FULL NETWORK CONNECTIVITY BY SELECTED GOVERNMENT USERS.
5. RAPID CIRCUIT ACQUISITION TO SELECTED USERS.
6. HAS POTENTIAL FOR ACCOMMODATING IMBEDDED/PRIVATE GOVERNMENT NETWORK.
7. COMPLETE FLEXIBILITY TO PROVIDE COMMUNICATION CAPACITY WHERE IT IS NEEDED THE MOST.
8. COMPATIBLE WITH DEVELOPING TECHNOLOGIES.
9. CAN ACCOMMODATE WIDEBAND LINKS.

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* THIS ASSUMES THAT APPROPRIATE MEASURES ARE TAKEN TO ENSURE THE SURVIVABILITY OF THE CONTROL FACILITIES (e.g., DISTRIBUTED CONTROL)

requirements, and the robustness/survivability of the overall network is improved. This robustness is further enhanced by the features of full connectivity and interoperabilty and the use of smaller terminals.

The major disadvantages of this concept revolve around the increased complexity associated with the network timing and control if TDMA is used, and with the development of a robust control system. In addition, this concept involves the start of a new program. Further development of the concept is necessary to identify the most cost-effective means for its implementation.

4.4 Cost Considerations

Earth terminals, incorporating the various features outlined above, are expected to cost about $400K each (dollar value in 1985). On the other hand, the number of commercial SATCOM terminals is estimated to be about 200. This yields a total initial earth segment cost (excluding operations and maintenance) of approximately $80 million. Note that each terminal is assumed to be capable of handling full-transponder transmission. For a typical transponder leasing cost of $150K/month the yearly leasing cost for 12 transponders (approximately 10,000 two-way circuits) would be about $22 million.

4.5 Other Concepts

Thin-route and mobile communications are other areas where SATCOM systems offer unique capabilities. The initial concept described earlier could be expanded to accommodate low-capacity thin-route users. This may be accomplished through the use of smaller terminals (e.g., transportable) that may be located near or at the user premises. Clearly, a requirement for this type of connectivity has to be identified (e.g., certain users who either require easily transportable terminals or who have little access to terrestrial connectivity). Communications between, or with, these types of terminals may be established through designated central or hub terminals that may be modified versions of those described earlier.

Due to recent and projected advances in SATCOM technology, the feasibility of using small, low-cost, transportable terminals is constantly improving. Mobile SATCOM concepts may also be desirable and should be taken into account in future developments.

PART 2

INTERNATIONAL SATCOM

SYSTEMS AND CONCEPTS

SECTION 5

CURRENT SYSTEMS AND APPLICATIONS

5.1 INTERNATIONAL SATCOM SYSTEMS

Although there are currently (1985) several regional SATCOM systems, INTELSAT and INMARSAT remain the dominant international SATCOM systems for the provision of fixed and mobile satellite communications, respectively. The following subsections describe the characteristics and capabilities of each of these systems and of the ANIK system, which can also provide international telecommunication capability for the DoD and other Government agencies. A discussion of regional systems and their potentials is also provided.

5.1.1 INTELSAT

The INTELSAT V series is the latest version of INTELSAT spacecraft. INTELSAT has satellites deployed over the three ocean regions: the Atlantic, the Pacific, and the Indian Ocean Regions (AOR, POR, IOR). Table 5-1 displays the typical characteristics of INTELSAT V.

The INTELSAT V spacecraft design life is 7 years. Services provided by the INTELSAT system include: secure, high-quality voice; video conferencing; television; data and facsimile. A number of modulation and access methods exist to accommodate the various INTELSAT global services are in use, these are:

- Frequency Division Multiplex/Frequency Modulation (FDM/FM)

Table 5-1. Summary of the Basic Characteristics of INTELSAT V

FREQ. BAND	NUMBER OF TRANS-PONDERS	TOTAL EFFECTIVE BANDWIDTH MHz	TRANSPONDER BANDWIDTH, MHz (NO. OF TRANSPONDERS)	EIRP* (dBW)	FREQUENCY REUSE
C-BAND	21	1352	77(4), 72(12), 36(5)	23.5-29	4 TIMES USING POLARIZATION (CIRCULAR) AND SPACIAL ISOLATION
Ku-BAND	6	780	77(2), 72(2), 241(12)	41.1-44.4	2 TIMES USING POLARIZATION (LINEAR) ISOLATION

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* EIRP LEVELS ARE PROVIDED FOR EDGE OF COVERAGES AND ARE GENERALLY HIGHER DEPENDING ON THE LOCATION WITHIN THE COVERAGE.

- Companded Frequency Division Multiplex/Frequency Modulation (CFDM/FM)
- Preassigned Single-Channel-per-Carrier/Quadrature Phase Shift Keying (SCPC/QPSK)
- Demand-assigned Single-Channel-per-Carrier/Quadrature Phase Shift Keying (SPADE)
- Single-Channel-per-Carrier/Companded Frequency Modulation (SCPC/CFM) for the VISTA Service (a thin route satellite service)
- Frequency Modulation Television with Associated Audio FM-Subcarrier (TV/FM)
- Time Division Multiple Access with Digital Speech Interpolation (TDMA/DSI) and without Digital Speech Interpolation (TDMA/DNI)
- Digital transmission at Intermediate Data Rates (IDR) using Quadrature Phase Shift Keying/Frequency Division Multiple Access Carriers (QPSK/FDMA)
- Digital transmission for INTELSAT Business Services (IBS) using Quadrature Phase Shift Keying/Frequency Division Multiple Access Carriers (QPSK/FDMA)

The INTELSAT V-A is an improved version of the basic INTELSAT V. Its performance specifications and characteristics are similar to INTELSAT V. Six additional transponders, however, are provided through frequency reuse, thus yielding a 25 percent increase in capacity. Figure 5-1 illustrates the typical coverages (AOR deployment).

The INTELSAT system uses several earth station standards of varying complexity and capabilities[5]. Typical earth station standards are highlighted in Table 5-2.

The primary function of the first three standards (A, B, and C) is to act as international gateways. The standard D earth stations are designed for the provision of thin route services; while the recently introduced standards E and F earth stations are designed for the provision of International Business Services (IBS). INTELSAT has also established other earth station standards for international and domestic use (standards G and Z, respectively), which allow use of modulation and access methods, as well as earth station types other than those summarized above. These standards are intended for users with specialized requirements.

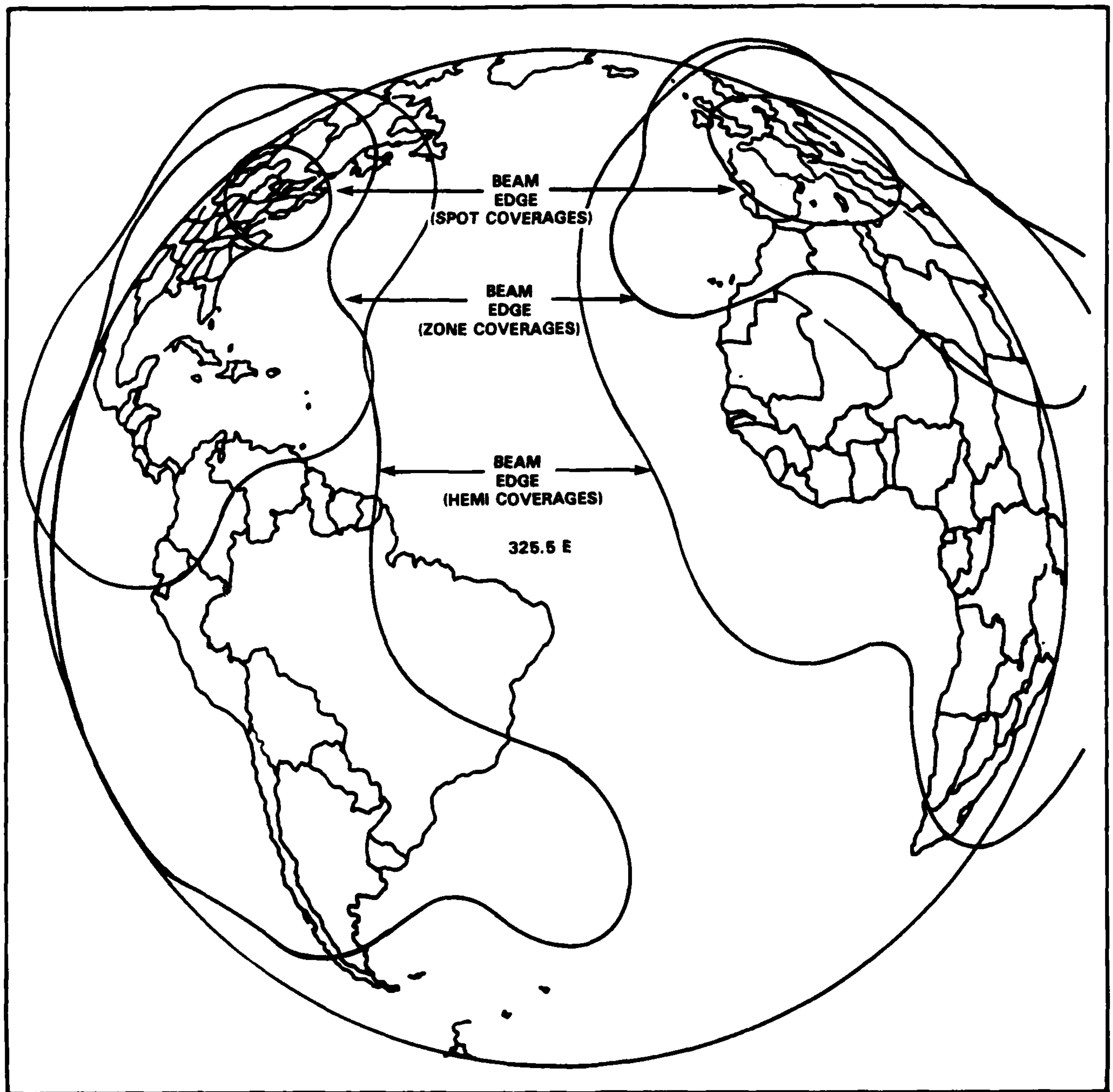

Figure 5-1
INTELSAT V-A
TYPICAL ANTENNA COVERAGE PATTERN

Table 5-2. Typical INTELSAT Earth Station Standards

STANDARD	SERVICE	FREQ. BAND	G/T (NOMINAL) dB/°K	ANTENNA DIAMETER, m
A	INTERNATIONAL	C	40.7	30
B	INTERNATIONAL	C	31.7	11
C	INTERNATIONAL	Ku	39	14-19
D-1	VISTA:	C	22.7	5.0
D-2	LOW DENSITY SERVICE	C	31.7	11.0
E-1	IBS	Ku	25	3.5
E-2	IBS	Ku	29	5.5
E-3	IBS	Ku	34	8.0
F-1	IBS	C	22.7	4.5
F-2	IBS	C	27.0	7.0
F-3	IBS	C	29.0	9.0

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5.1.2 INMARSAT

The INMARSAT space segment consists of three types of satellites: MARISAT, MARECS, AND INTELSAT V-MCS. The three MARISAT satellites leased from COMSAT General have been augmented by leased space segment capacity on two European Space Agency MARECS satellites and three INTELSAT V satellites that incorporate a Maritime Communication Subsystem (MCS).

The INMARSAT system uses both L and C-band frequencies as follows: ship-to-shore communications use L-band (1.6 GHz band) for uplink (ship to satellite) and C-band (4 GHz) for the downlink (satellite to shore). Shore-to-ship communications use C-band (6 GHz) for uplink and L-band (1.5 GHz) for downlink (satellite to ship). Typical INMARSAT space segment characteristics are summarized in Table 5-3.

Table 5-3. Typical INMARSAT Space Segment Characteristics

CHARACTERISTICS	MARISAT	MARECS	INTELSAT-V (MCS[a])
C- TO L-BAND REPEATER			
RECEIVE G/T, dBK	−19.6	−15.0	−12.1
L-BAND EIRP, dBW	27.0	34.5	33.0
CAPACITY, CHANNELS[b]	12	60	35
L-TO-C REPEATER			
RECEIVE G/T, dBK	−17.0	−11.2	−13.0
C-BAND EIRP, dBW	18.8	16.5	20.0
CAPACITY, CHANNELS	20	90	120

[a]MARITIME COMMUNICATION SUBSYSTEM.
[b]CAPACITIES COULD BE APPROXIMATELY DOUBLED BY VOICE ACTIVATION ON TELEPHONE CARRIERS IN THE SHORE-TO-SHIP DIRECTION.

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The INMARSAT earth segment consists of two types of earth stations:

1. Coastal earth stations--These are owned and operated by INMARSAT signatories around the world. There are about a dozen such earth stations worldwide with several more being planned or under construction. These earth stations interface with international public switched networks. They are 10-13 meters in diameter (antenna) and are capable of up to 70 dBW of EIRP per carrier.

2. Ship earth stations--These earth stations are owned and operated by ship owners. Their average cost is about $30K; they incorporate autotrack equipment to enable the antenna beam to remain pointed at the satellite. The antenna diameter for these stations range from .9 to 1.2 meters.

Services provided by the INMARSAT system include: telephone (duplex, analog/companded FM); Telex (50 Baud); telegram; voice band data, facsimile and slow scan TV; 56 kbps high-speed ship-to-shore data transmission; 1 Mbps data (ship

to shore) using special ship earth stations; group call (broadcast) to ships of a particular fleet or national origin and to ships in a given geographical region; and distress and safety services.

5.1.3 Regional Systems

The significant growth in demand for commercial satellite services such as telephony (both trunking and thin route) and television transmission has initiated the construction and deployment of multiple regional and domestic satellite systems worldwide. Regional satellite systems include:

- Indonesian/ASEAN/Papua New Guinea
- European Systems
- Arabsat

The world's first regional system, that for Indonesia, ASEAN, and Papua New Guinea, operates at C-band and was improved and augmented in mid-1983. The second system, the European Communication Satellite (ECS) System, operates at Ku-band and was first launched in June 1983. The system is managed by the European Telecommunications Satellite Organization, EUTELSAT. The EUTELSAT services were introduced to complement the terrestrial network routing public international telecommunications. The typical ECS satellite capacity is comparable to that of INTELSAT V (12,000 circuits and 2 TV channels). Each ECS satellite carries twelve 80 MHz transponders (∿1800 telephone circuits) of which nine transponders may be powered simultaneously. The third system, Arabsat, was also introduced in 1985 to provide C-band communications and S-band television to more than 20 Arab states.

5.1.4 ANIK

The ANIK C satellite provides 16 Ku-band transponders, each having a bandwidth of 54 MHz. The nominal transponder EIRP level is 48 dBW. Linear polarization is used. The services provided include voice, telegraph, data, and television transmission. The ANIK D satellite operates at C-band and its characteristics are similar to those listed in Section 2.1 for domestic C-band satellites. The ANIK system provides an example of an existing international resource currently being used by the DoD.

5.2 INTERNATIONAL COMMERCIAL SATELLITE USE BY DoD

Unlike domestic commercial satellite use by the DoD, there is only one primary way in which the international commercial satellite service is obtained: that is by leasing individual circuits. The circuits range from standard voice-grade analog circuits, used for such purposes as interswitch trunking in the AUTOVON network, to point-to-point dedicated data circuits up to 9.6 kbps. A small number of 50 kbps circuits are also provided for wideband secure voice communications and some 1.544 Mbps T-carrier interswitch trunks are also provided.

The DoD presently leases approximately 600 international circuits from over a dozen international carriers[6]. Of these, approximately half are accommodated via satellite at a cost of over $10M per year, and, of the satellite circuits over two thirds are used for voice traffic. The remainder are predominately narrowband data (less than 50 kbps) with a few wideband data circuits. Table 5-4 shows this break-out as of March 1985.

Table 5-4. DoD Use of International Circuits via Satellite (as of Mar '85)

	ATLANTIC	PACIFIC	CARIBBEAN	TOTAL
WIDEBAND * DATA > 50 Kbps	2	11	0	13
NARROWBAND DATA ≤ 50 Kbps	28	36	12	76
VOICE	101	82	37	220
TOTAL	131	129	49	309

* INCLUDES 1.544 Mbps T1 CIRCUITS

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These circuits typically consist of a leased terrestrial tail circuit at each end, connecting to an international satellite gateway in the host country. Each country has at present, relatively few of these gateways. Many smaller countries have only one. Because of this, the length of the terrestrial tail circuits can be quite long.

These international circuits share the same lack of flexibility as their domestic counterparts. In this sense, there is very little to differentiate satellite-provided circuits from those provided by undersea cables. However, having at least one gateway in each country does avert the need to involve a third country (where the cable head is located) in an international lease.

This limited number of gateways could be considered the proverbial weak link in this communications chain and does indicate a substantial vulnerability. In addition, these gateways are not particularly accessible to widely dispersed remote users. Remedies for this dificiency are discussed in Section 7.

SECTION 6

MID-TERM SYSTEMS

6.1 INTERNATIONAL SATCOM SYSTEMS

INTELSAT and INMARSAT will continue to be the major international systems for the mid-term (1986-1991), although new generations of more advanced spacecraft will be introduced. The new capabilities of these systems, as well as some other systems that have the potential of augmenting the DoD telecommunications resources, are discussed in the following subsections.

6.1.1 INTELSAT

INTELSAT VI typifies mid-term commercial SATCOM technology. Deployment of this spacecraft is expected within 1986-1987. The INTELSAT VI space segment provides six times frequency reuse through polarization and spacial isolation. It also incorporates new technologies, such as satellite switched TDMA. Solid State Power Amplifiers (SSPAs) are being used in addition to TWTAs. Typical INTELSAT VI characteristics are summarized in Table 6-1.

Table 6-1. INTELSAT VI Typical Characteristics

FREQ. BAND	NUMBER OF TRANS-PONDERS	TOTAL EFFECTIVE BANDWIDTH MHz	TRANS-PONDER BANDWIDTH MHz	EIRP dBW	POLARI-ZATION
C	38	1357	36, 72	23.5-31	CIRCULAR
Ku	10	780	72, 241	41.4-44.4	LINEAR

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The INTELSAT VI spacecraft has a 10-year design life. It will provide two global, two hemispheric and four zone coverages at C-band, and two spot coverages at Ku-band. Table 6-2 summarizes the launch dates, the locations, and the coverages for the INTELSAT VI satellite. Figure 6-1 illustrates the typical antenna coverages corresponding to a satellite deployed over the Atlantic Ocean Region (AOR). *The earth station* standards and the *services provided by the system are the same* as described in Section 5.1 for the near-term.

Table 6-2. INTELSAT VI Launch Dates and Antenna Coverage Patterns

REGION	SATELLITE LOCATION (°EAST)	SERVICE	APPROXIMATE TIME FRAME	ANTENNA COVERAGE PATTERNS		
				HEMISPHERIC	ZONE	SPOT
AOR	325.5 335.5	PRIMARY	1991- 1987-	X	X	X
IOR	60	PRIMARY	1988-	X	X	
POR	174	PRIMARY	–	X	X	

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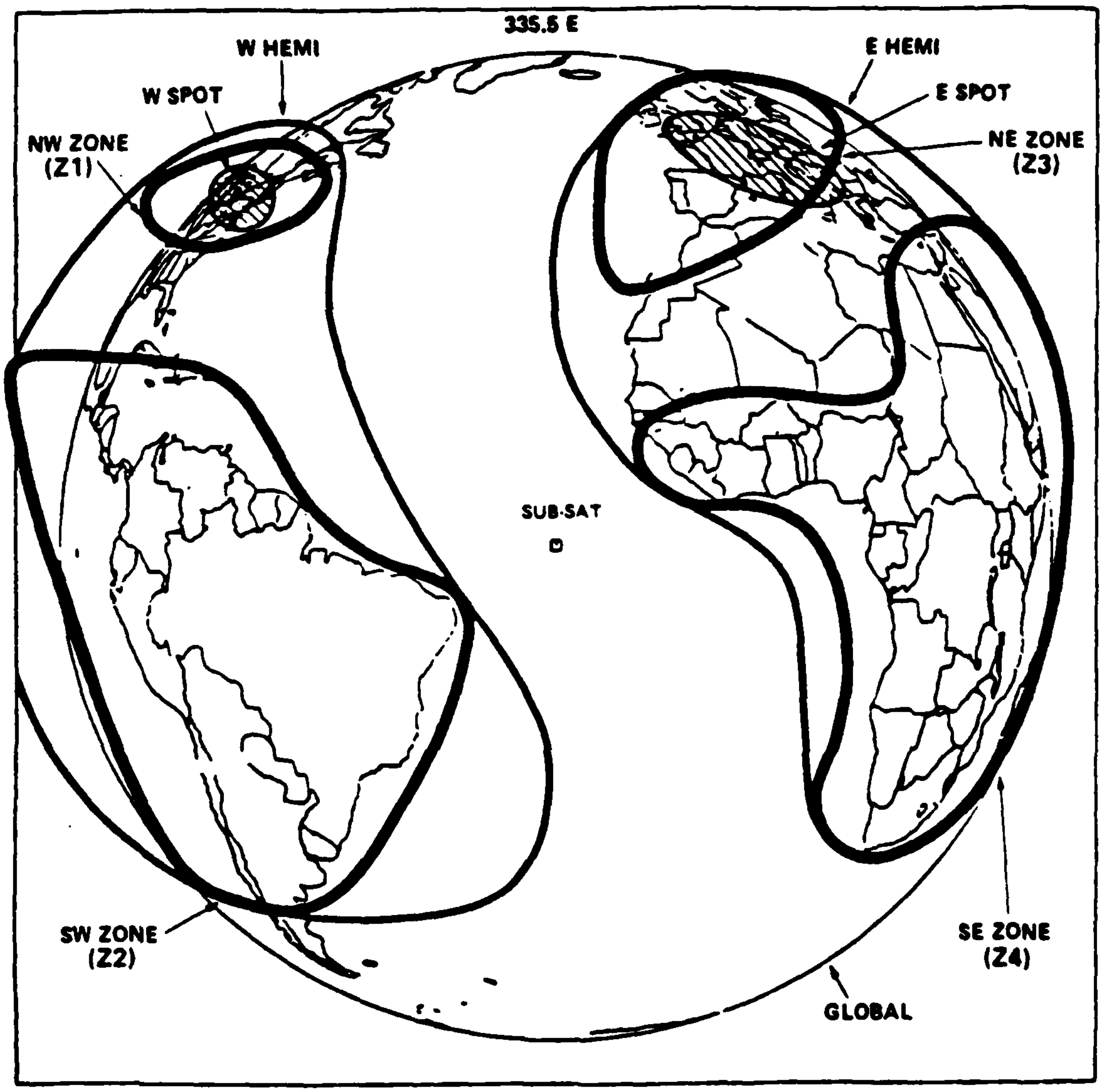
NOTE THAT THE GLOBAL PATTERN COVERS THE ENTIRE EARTH's DISK (SEE FIGURE 6-1).

Increased demand for the various services is expected through the mid-term, particularly for International Business Satellite (IBS) services, (e.g., teleconferencing), which was recently introduced. This service is not normally intended to be used for public switched telephony. IBS services will be provided using *standards A, B, C, E and/or F earth stations*. Connectivity between these earth stations can be established using either C- or Ku-band transponders. Cross strapping between C- and Ku-bands is also provided. The IBS digital



NOTE:

1. THE EAST 14/11 GHz SPOT BEAM IS STEERABLE OVER THE FULL EARTH'S DISC.
2. THE WEST 14/11 GHz SPOT BEAM IS STEERABLE OVER THE WESTERN HEMISPHERE ONLY.

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Figure 6-1.
INTELSAT VI
TYPICAL ANTENNA COVERAGE PATTERN

carriers use Quadrature Phase-Shift Keying (QPSK) modulation with Frequency Division Multiple Access (FDMA), and carriers will be assigned fixed frequencies within a given transponder. QPSK/TDMA/FDMA, TDM/QPSK/FDMA, and QPSK FDMA terminals may be employed for specialized networks but require the review and approval of INTELSAT. Encoding, scrambling, and encryption may be employed. IBS carrier information rates range from 64 kbps up to 8.448 Mbps (Transmission rates can be up to 18.6 Mbps if rate 1/2 Forward Error Correction (FEC) coding is used).

6.1.2 INMARSAT

Introduction of the second generation of INMARSAT satellites is expected in the late mid-term/early far-term time frames[7]. The new system will enable INMARSAT to expand the user population, support new earth station standards, and incorporate digital modulation and coding.

The Future Global Maritime Distress and Safety System (FGMDSS) will integrate and coordinate use of satellite and terrestrial radio links for improved distress and safety services including:

- Simple automatic distress alerting, mainly using Emergency Position Indicating Beacons (EIRPBs).
- Improved search and rescue communications.
- Automatic on-board reception of distress messages as well as navigational and meteorological information for the ship's area of interest.

6.1.3 Regional Systems

In addition to the various existing regional systems discussed in the previous section, three other regional systems

(Andean, African and Pacific Basin) are being planned for the late 1980s[8]. Table 6-3 summarizes the salient features of these systems and Table 6-4 summarizes typical characteristics of the spacecraft each system is expected to employ.

Table 6-3. Regional Systems Summary Description

REGION	OPERATOR	COVERAGE	SERVICES	LAUNCHING AGENCY
ANDEAN	ASETA QUITO, ECUADOR	COLOMBIA, PERU, VENEZUELA, BOLIVIA, ECUADOR, CHILE, AND POSSIBLY PANAMA	TV, TELEPHONY, DATA, RURAL COMMUNICATIONS	NASA, SHUTTLE; ARIANESPACE
AFRICAN	UAPT/PATU/OAU BRAZZAVILLE, KINSHASA, ZAIRE; AND ADDIS ABABA, ETHIOPIA	AFRICAN CONTINENT	TV, TELEPHONY, DATA, RURAL COMMUNICATIONS TO 4.5 TO 8 m EARTH STATIONS	NASA, SHUTTLE; ARIANESPACE
PACIFIC BASIN		PACIFIC ISLANDS, FRENCH POLYNESIA IN THE EAST TO GUAM, MICRONESIA, AND MARIANAS IN THE WEST	TV, TELEPHONY, REMOTE ISLAND AND RURAL AREA COMMUNICATIONS TO 4.5 m EARTH STATIONS	NASA, SHUTTLE

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Table 6-4. Spacecraft Characteristics Comparison

CHARACTERISTICS	AFRICAN	PACIFIC BASIN	ANDEAN
FREQUENCY BAND	C	C	C
MISSION LIFE, YR.	10	10	10
CHANNELS	12 TO 24	8 TO 12	12 TO 24
BANDWIDTH, MHz	36	36	36
POWER, W	5 TO 20	5 TO 20	5 TO 20
EIRP, dBW	29 TO 32	32 TO 40	32 TO 36
NUMBER OF SPACECRAFT	2	2	2
FIRST LAUNCH DATE	1988	1987	1989

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6.1.4 Other Systems

The mid-term follow-on to ANIK C/D satellites will emphasize new technology for improved overall system cost effectiveness. The capabilities include on-board signal processing, including Satellite Switched-TDMA, switchable antenna coverage of CONUS and/or Canada, flexibility in feeding uplink channels to different downlink antennas and use of SSPAs in place of TWTAs. The TDRSS satellite incorporates advanced technologies and provides 12 C-band and 4 Ku-band channels (250 Mbps per channel). The SS-TDMA capability is included. Frequency reuse is provided by spacial and cross-polarization isolation.

6.2 NETWORKING AND LEASING CONSIDERATION

This section describes some of the issues related to leasing space segment capacity and to the leasing and/or operation of earth segment resources.

6.2.1 Space Segment Capacity

Access from/to a given country using the INTELSAT space segment would normally be negotiated and established through the country's INTELSAT signatory. In the U.S., this is COMSAT; in foreign countries, this is normally a governmental entity (i.e., PT&T). Space segment leasing costs are paid as follows: COMSAT's charges cover the U.S. portion of the satellite link (e.g., uplink); the foreign government's communications entity charges cover the remaining portion of the link (e.g., downlink). Normally, communication carriers', (such as AT&T) charges include the space segment charges above, as well as other charges for using other communications links and facilities (such as terrestrial cables and earth stations), and profit. Although space segment or individual transponder

failures are unlikely, options for switching in the case of a failure, among transponders, frequencies, and/or satellites can be arranged as part of the initial leasing agreement.

Either voice channels could be leased (for analog or digital voice traffic), or transponders/transponder fractions could be leased for digital traffic that may include voice. AT&T, for example, currently leases approximately 17,000 voice channels at a cost of approximately $1,025 per voice channel per month. The recently introduced IBS services using the INTELSAT Ku-band transponders is designed to accommodate the requirements of individual users, business and private networks. As indicated earlier, new earth station standards have been approved for this purpose. The portions of the Ku-band transponder which may be leased would accommodate multiples of 64 kbps up to 2 Mbps of information.

Currently under active consideration by INTELSAT is a plan that would allow the leasing or the sale of INTELSAT transponders to individual countries for their own domestic use. This plan has emerged because of the increased competition within the domestic and regional/international SATCOM market. Currently, INTELSAT leases about 40 transponders to individual countries for their own domestic use, generally on a preemptible basis (with the proviso that INTELSAT could reclaim the transponder if needed for the international network). The new plan would make available INTELSAT spare transponders for individual countries to lease or buy. The new plan would give the buyer or leasee full, non-preemptible rights to the transponder, the purchase price of which is estimated at $3 to $5 million. The number of idle INTELSAT transponders is estimated to be about 150.

6.2.2 Acquisition of Earth Segment Resources

Operators of U.S. earth stations accessing commercial bands would have to fall under FCC jurisdictions. One DoD option for accommodating such requirements would be to have its earth stations leased from, and/or operated by a U.S. commercial entity. This may prove economically attractive because of the newly introduced competition in the ownership and operation of U.S. international earth stations. COMSAT is no longer the only U.S. entity that can own and operate earth stations accessing the INTELSAT space segment.

With respect to earth stations located in foreign countries and accessing international commercial SATCOMs, the DoD does not currently own such facilities. There is, however, the possiblity of having DoD-dedicated earth stations operated by the foreign governments' communications entity (e.g., PT&T) under some form of a leasing arrangement. The arrangements for having these earth stations leased from, and/or operated by, a foreign government agency, a foreign company, or a U.S. company are heavily dependent on the foreign country in question and its government and must be negotiated in detail.

Ownership of terrestrial links in foreign countries is likely to be extremely difficult (particularly for cable) to obtain. The right of way is difficult to get. This is generally true for links extending beyond DoD bases and facilities. Terrestrial links could be leased or provided using radio relay equipment.

SECTION 7

FAR-TERM SYSTEMS AND CONCEPTS

In this section, three far-term (1992-2000) main topics are considered: the first topic identifies the various international commercial SATCOM systems, resources, and technologies (subsection 7.1 and 7.2). The second topic (subsection 7.3) provides a broad characterization of current and potential far-term DoD users in terms of their geographic distribution/coverage requirements, connectivity, networking, and traffic types. The third topic (subsections 7.4 and 7.5) identifies concepts that would increase the capacity and improve the robustness and flexibility of the overall DoD telecommunications assets cost effectively. A discussion of concept applications is also presented.

7.1 *INTERNATIONAL SATCOM SYSTEMS*

The basic systems identified in Section 6.1 for the mid-term are expected to continue their services through the far-term.

7.1.1 INTELSAT

The INTELSAT VI series of spacecraft and follow-on is expected to continue to be the primary INTELSAT resource through the mid-to-late far-term. Beyond 1995, however, new generations of INTELSAT spacecraft, incorporating new technologies, may be introduced.

7.1.2 INMARSAT

The third generation INMARSAT space segment envisioned for the mid-1990s is expected to incorporate spot beam coverages and

L-band frequency reuse. In addition, extended services for land mobile and aeronautical mobile users is under study.

New digital earth station (standard-C) concepts are being studied and would incorporate:

- Lightweight, compact installations for message services on the order of 1 kbps
- Quasi-omni directional antenna of ≃ 3 dBi gain
- Improved operation at low elevation angles
- Simple low power amplifier
- FEC rate 1/2 Viterbi decoding

The new station would cost about $6K (1/5 that of standard A). The message services are to include distress alerting, data graphics, image, and coded text. The new system will provide improved group-call capabilities. This will allow broadcast messages, such as telex, facsimile, weather maps, and news broadcasts to be sent to specified areas and/or groups of ships equipped with receive-only terminals and to airborne systems featuring 400/600 bps for air traffic control, and 2.4-9.6 kbps voice and packet data. The antenna gains of these terminals are envisioned to be in the 8-12 dBi range.

7.1.3 Other Systems: U.S.-Owned International SATCOM

In addition to the ANIK, the TDRSS, and other regional systems discussed in Section 6.1, commercial U.S.-owned international SATCOM systems may emerge in the far-term. Such systems require the approval of the nations being served, as well as the approval of INTELSAT's Board of Governers. ORION

is an example of a system that has acquired U.S. support but still requires the other approvals. In addition to leasing the resources which could be made available, such systems have the potential for carrying a Government or DoD dedicated communications package. New technologies such as Ka-band, on-board processing/switching, and narrow/hopping beams could be incorporated, thus significantly enhancing the capabilities and usefulness (see Section 7.2) of commercial SATCOM, particularly in accommodating DoD user and traffic requirements.

7.2 NEW TECHNOLOGY

Far-term international SATCOM technolgies and their benefits are basically those discussed in Section 4.2 for domestic SATCOM. Introduction of these technologies to international SATCOM (basically INTELSAT) may not take place until the second half of the far-term (after 1995), if not beyond.

7.3 TRAFFIC AND CONNECTIVITY CONSIDERATIONS

Potential DoD international SATCOM users in the far-term can be broadly characterized according to their geographical distribution, coverage, connectivity requirements, and traffic types/transmission rates. The discussion here will be general and only those features that are used in connection with the concept description and applications in Section 7.4 are emphasized.

7.3.1 Regional/Theater Communications: Regions with Terrestrial Systems

This scenario involves DoD users that are located within a given region and whose connectivity requirements are primarily within that region (although a limited number of these users may also have some requirements for inter-regional connectivity). Furthermore, the region is assumed to have abundant terrestrial resources. In Europe, for example, terrestrial networks are the backbone for regional communications. Users in this category may be further classified as follows:

- Wideband users (1 Mbps-50 Mbps): these users could belong to one of two subcategories. The first subcategory requires point-to-point communications, employing both fixed and transportable sites; the second subcategory involves point-to-multipoint communications, such as teleconferencing or the distribution of multiplexed data and/or voice from one site to several other sites. Again, fixed and/or transportable terminals may be used for this purpose.
- Narrowband users ($\leq$ 64 kbps): This type of user includes point-to-point dedicated or common-user connectivities
- Mobile Users: This type of user requires communications while in motion. The requirements include point-to-point and point-to-multipoint connectivity.

7.3.2 Regional/Theater Communications: Regions with Little or no Terrestrial/Undersea Systems

Again, this scenario involves users within a given region who require connectivity primarily within that region. In this case, however, the region is assumed to have little or no terrestrial (or undersea) links. Africa and the Pacific are examples of such environments. In the Pacific, for example,

7.3.3 Transoceanic Communications

Inter-regional communications generally involve communications across the ocean(s). Commercial transoceanic connectivity is currently provided by SATCOM and/or undersea cables through the use of large gateways and major switching centers. Terrestrial links are used to provide access to these gateways and switching centers.

In addition to the three user classes presented in Section 7.3.1, DoD users with transoceanic connectivity requirements also include very wideband users (100 Mbps-1 Gbps). This type of user generally requires point-to-point communications with fixed sites.

7.4 INTERNATIONAL SATCOM CONCEPTS

As indicated for the domestic case, international commercial SATCOM should constitute only one element of an integrated communication media incorporating MILSATCOM, terrestrial and undersea cables, and microwave links. Unlike the domestic case, however, international SATCOM plays a bigger and more critical role in accommodating a larger percentage of DoD international communications requirements.

7.4.1 Basic Concepts

This section outlines far term concepts that would increase the capacity, improve the robustness and the flexibility of the overall DoD telecommunications assets. It should be indicated

that the treatment of the proposed concepts will be generic. A more detailed treatment requires further development of these concepts. In this context, two concepts are proposed as follows:

- <u>Expanded Common User Network</u>: This concept calls for expanding the existing worldwide, common-user, DoD network (Defense Communication System, DCS) through the establishment of an international commercial subnetwork that is loosely interfaced (or coupled) with the existing or core DoD network. This coupling would be accomplished to improve the overall network robustness by taking advantage of the media diversity within DCS. This subnetwork would incorporate a family of interoperable commercial terminals of varying sizes (capacities and capabilities). These terminals are to be distributed as an overlay to the core network. Small terminals could be located at or near the user premises. The international commercial SATCOM subnetwork would augment the capacity and connectivity of the overall network, as well as provide additional links and alternate routing capabilities for improved robustness.

- <u>Augmented Point-to-Point Wideband Connectivity</u>: This concept addresses point-to-point very wideband users (that are not part of the common user network), whereby international commercial SATCOM could be used to provide additional capacity to complement other media. With this additional capacity, the availability of MILSATCOM resources may be increased for more critical traffic/users.

7.4.2 Concepts Features

The key features of the proposed concepts fall into several areas as summarized below:

- Terminal and Networking Configurations. This concept features an increase in the number of small SATCOM terminals. These small terminals are to be installed on, or near, the user premises and concentrations and at selected network nodes.

  Single or double hop connectivity may be established depending on the terminal size. The networking configurations are to incorporate mesh, star, and point-to-point dedicated links. Three types of terminals are envisioned as indicated in Table 7-1.

  In connection with the star configuration, augmented versions of Type-2 terminals are to be the designated hub or central nodes. Furthermore, all terminals will be capable of regional and/or international communications.

- Alternate Routing. In addition to the increase in the overall network capacity, the proposed DCS augmentation introduces new links within the DoD network. The introduction of switching capabilities at the network nodes can further take advantage of these additional links to allow alternate routing of users' traffic over all connectivity means, including commercial, DSCS, terrestrial (or undersea).

Table 7-1. Terminal and Network Configurations

TERMINAL TYPE	CANDIDATE USER/TRAFFIC	APPROXIMATE ANTENNA SIZE*	INTENDED USE OR CONFIGURATION**
TYPE-1	NARROWBAND	2-3m	STAR
TYPE-2	WIDEBAND (TRANSMISSION EQUIVALENT TO 1 OR MORE T1 CARRIERS)	5m	MESH
TYPE-3	VERY WIDEBAND	TO BE DETERMINED	POINT-TO-POINT DEDICATED

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*ASSUMES Ku-BAND OPERATION

** ONE CONFIGURATION MAY DOMINATE IN SOME REGIONS, WHILE A MIX OF CONFIGURATIONS MAY BE MORE APPROPRIATE IN OTHERS DEPENDING ON USER DISTRIBUTION, REQUIREMENTS, AND THE AVAILABILITY OF OTHER RESOURCES (e.g., TERRESTRIAL).

Alternate routing promotes and makes effective use of the mix of communications media and capabilities, and would further contribute to provide a more robust network.

- Demand Assignment Multiple Access (DAMA): Demand Assignment Multiple Access could be incorporated for improved efficiency. Dedicated link service would be provided when needed through the use of network controllers installed at designated switches.

- Priority Systems. Priority systems could also be implemented to ensure that critical users are supported. Commercial systems could be used to provide high-speed augmentation of MILSATCOM for administrative and support traffic. MILSATCOM assets availability for critical, time-sensitive traffic would be increased. Terminal interfaces would be used that the network switches could access so that pathways would be user transparent.

7.4.3 Application Scenarios:

This section illustrates how the concept applies to the various connectivity scenarios outlined in Section 7.3.

7.4.3.1 Regional/Theater Communications: Regions with Terrestrial Networks

As in the domestic case, terrestrial links will continue to be the primary resource. In this environment, the recommended concept will involve the addition of an overlay network. The primary features of this augmentation include:

- Type-2 terminals
- Mesh connectivity
- Alternate Routing
- Demand Assignment Multiple Access (DAMA)
- Priority Systems.

7.4.3.2 Regional/Theater Communications: Regions with Little or no Terrestrial or Undersea Systems

In this case, a mix of Type-1 and Type-2 terminals (allocated according to traffic requirements) is envisioned. The number of Type-2 terminals is expected to be small and will primarily serve as the central/hub terminals within the star configuration. (Mesh connectivity among the Type-2 terminals will also be available).

7.4.3.3 Transoceanic Communications:

Transoceanic and/or inter-regional connectivity may be established using a mix of Type-1 and Type-2 terminals, and a combination of mesh and star configurations depending on user locations and their requirements.

The primary features associated with this application include:

- Alternate routing (through switches that would make use of the additional links).
- Terminals that are at or near the user premises would bypass major international gateways and switching centers.
- DAMA: for flexible and efficient allocation of capacity to users.
- Priority systems: higher priority and critical traffic may be assigned to MILSAT and/or communicated first.

In addition, commercial SATCOM systems can provide added capacity for point-to-point very wideband users. In this case, commercial SATCOM may be used to provide an additional link in parallel with an existing MILSATCOM link to offer increased capacity or data throughput. This application is advantageous for point-to-point users with large amounts of capacity, where traffic may be partitioned and transmitted over both links. Type-3 terminals would be used for this purpose. This application allows increasing the link capacity at lower cost than by adding MILSATCOM. The availability of existing military systems for accommodating critical time-sensitive traffic would also be increased.

7.4.4 Concepts Benefits

The primary benefits associated with the proposed concepts are summarized below. Note that the features to which some of these benefits are attributed are also indicated.

- Increased Capacity
- Improved robustness: Although commercial assets lack the survivability and anti-jamming features of military systems, improved robustness or survivability refers to improved networking, connectivity, and interoperability in comparison with existing practices.
- Smaller terminals closer to the user, and consequently:
  - Bypassing major international gateways and switching centers, thus reducing the link vulnerability and costs associated with leasing terrestrial lines.
  - Increasing the number of terminals and network nodes
  - Allowing more easily transportable terminals (particularly type-1).
- Alternate routing of users' traffic over all connectivity means, and therefore:
  - Promoting the mix of media within DCS (i.e., media diversity)
  - Reducing dependency on an individual medium (particularly commercial) or a node
  - Allowing access to the network by all users (including remote users)
  - Increasing MILSATCOM availability to critical users
  - Allowing connectivity between dissimilar terminals (e.g., DSCS, Commercial)
- Efficient use of capacity through Demand Assignment Multiple Access (DAMA)
- Coordinated allocation of media and resources through the use of priority systems

- Peacetime use of additional capacity
- Standardized use of commercial assets within DCS.

7.5 IMPROVED LEASING

DCA, GSA, and other Government departments and agencies lease commercial communications, DCA alone is spending at the rate of $10.3M per year for international SATCOM leasing. Cost could be reduced if this leasing were coordinated across all Government agencies to insure against unwanted or unneeded redundancies. A consolidated leasing office would offer additional controls over Government SATCOM leasing and provide further savings through the sharing of communications services. Leasing of SATCOM service could be emphasized rather than leasing of channels, transponders, or satellites.

The advantages of consolidated leasing include:

- More effective use of leased links through sharing by compatible users. Multiplexing or DAMA techniques could provide service to more users than dedicated links.
- Consolidated management of leasing by DCA, military services, DoD agencies, and GSA. Consolidated leasing provides a clearer picture of DoD leasing.
- The provision of single point of interface for commercial SATCOM on DSN, thus allowing standardization of interoperability requirements and a more comprehensive listing of requirements for SATCOM services.
- Improved availability, since leasing services would require the SATCOM company to provide backup capability to an agreed-upon level.

Some of the disadvantages are:

- Users may resist relinquishing control of leases. They may view centralized control as not in their best interests.
- Carriers may charge higher rates based on an increased transponder duty cycle to recoup loss in fees.
- Expenses to set up a consolidated management office should be assessed carefully to ensure that they do not outweigh the cost savings and other benefits.
- Backup capacity could be required since the higher duty cycle of the leased links may reduce the ability to accommodate traffic surges.

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This document reviews existing and planned, domestic and international commercial SATCOM assets for each of the following 3 time frames: Current (1985), mid-term (1986-1991) and far-term (1992-2000). In addition, current DoD use of these assets is summarized and assessed. Summary descriptions of some major mid-term DoD systems, networks and architectures are given. Alternative far-term concepts for the use of commercial SATCOM as a complement to MILSATs in providing additional service and robust connectivity are also presented.

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